

# **Oceanographic Measurement Surveys Using a Custom AUV: Mixing Induced in the Upper Mixed Layer on a Continental Shelf during Adverse Weather Conditions**

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## **LONG-TERM GOALS**

The principal long-term goals of this work are to (i) contribute to the development of physics-based numerical models for accurate assessment and prediction of the ocean environment, and (ii) develop state of the art system for oceanographic observations from one or more AUV surveyor platforms. Our contribution is based on developing accurate parameterization of the active small-scale processes in the water column through observations from fixed and mobile AUV platforms. The parameterizations are needed to correctly model subgrid scale processes in predictive numerical models. The aim is to develop the necessary data bank to help parameterize the sub-grid processes under various, measured background conditions.

## **OBJECTIVES**

(i) Determine, using a custom AUV platform, the structure of the subsurface oceanic layer, including distribution of bubbles, currents, thermohaline fluxes, and rates of dissipation and mixing, together with the structure of the close-bottom boundary layer during high onshore wind events. The aim is to parameterize the physical processes induced in the subsurface layer and the bottom boundary layer by the atmospheric forcing for incorporation and validation of models of these processes. (ii) Develop a custom, dedicated surveyor AUV, for making quality oceanographic measurements for use in the proposed and future oceanographic experiments under a variety of scenarios.

## **APPROACH**

The following tasks were identified in pursuing the objectives:

*Task 1 - Development of a custom AUV.* Using previous experience with the Ocean Explorer as a basis, a custom vehicle will be developed taking account of the considerations such as vibration isolation of the AUV machinery from the payload section and chatter-free control. For greater versatility, it would be desirable to increase the depth rating from 300m to a 1000m, say. Such an increase will allow future missions in the Gulf Stream and will involve modification of the pressure hull. The robustness of the vehicle and its operation to stormy conditions will also be a requirement.

We will work closely with the Bluefin AUV development team to ensure that the necessary requirements are met and details of the navigational and positional accuracies are determined. The present Odyssey III will require some modification to accommodate custom sensor systems developed previously at FAU under this effort.

*Task 2 - Implementation of the oceanographic measurement sensors.* The sensor system on the custom AUV will include: a GPS navigation system, a compass, a motion sensor package, an upward (600kHz) and a downward-looking (300kHz) ADCPs, a Seabird FastCAT CTD package, a microstructure turbulence package, consisting of two shear probes, and fast response conductivity and temperature sensors, a broadband (6-196kHz) bubble resonator designed by David Farmer's group, two 300Hz sidescan and one vertical look sonars, and an ARGOS communication system. The possibility of implementation of a single custom upward and downward looking ADCP, of the type mounted on the REMUS vehicle, will be explored with RDI.

*Task 3 - Test of vehicle and sensor system operation (Now scheduled for summer 2003).* The mixed layer mission of July 1999 will be repeated as part of the test, extending the scope to include measurements afforded by the additional sensors and operation in high wind conditions. The object will be to make turbulence measurements and gain experience with making the bubble measurement with the new vehicle during high southeast wind conditions.

*Task 4 - Analysis of data acquired during fall 2000.* Analyze bubble and turbulence distribution measurements carried out during previous year.

*Task 5 - A Fall Experiment in high onshore wind conditions.* A field experiment (scheduled in fall 2003) involving an AUV survey of the upper mixed layer under high onshore wind conditions at the SFTF site is proposed.

## **WORK COMPLETED**

Task 1: Bluefin's Odyssey III vehicle, with a depth rating of 3000m, is being built (see Figure 1). Vehicle delivery has been delayed and is now scheduled for 11/30/03. Acceptance tests are due in December 2003. These will be carried out at AUTEC in the Bahamas. The vehicle will be named after Geoffrey Ingram Taylor (GI Taylor).

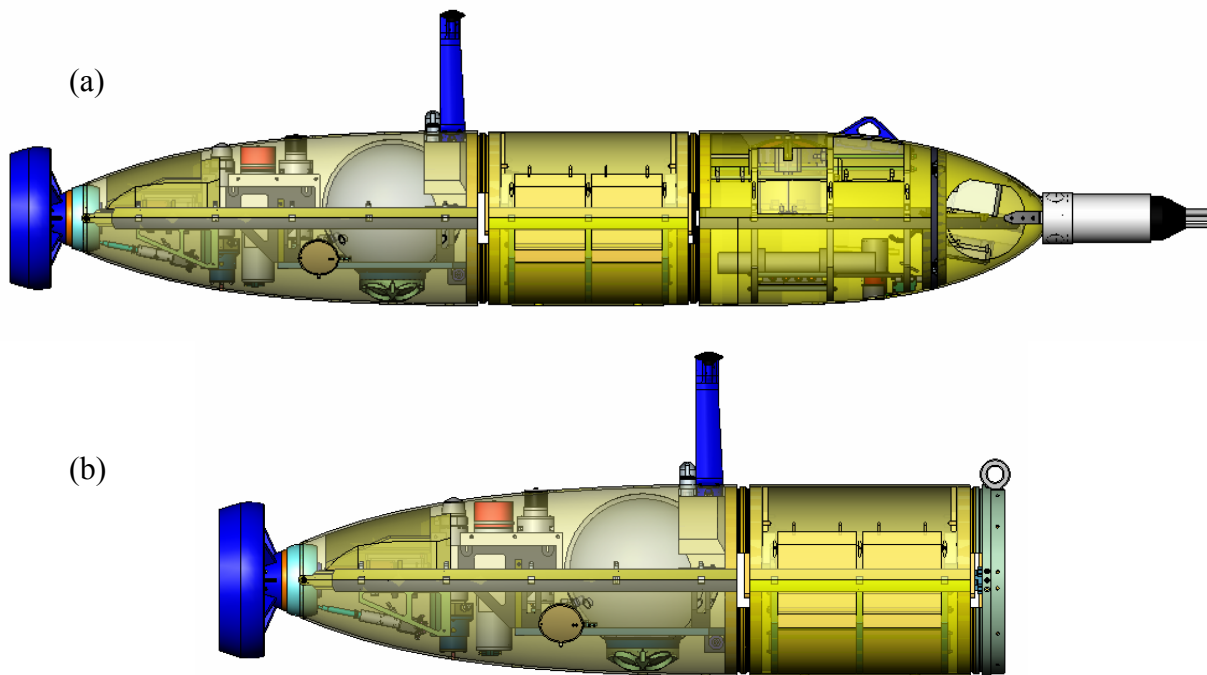
Tasks 2, 3: Since both the Odyssey III and the OEX are both 21" vehicles, a work around has been found so that the payload sections developed for the OEX on previous funding can be migrated to the new vehicle. This will facilitate early transition to deployment. Specifically, in facilitating Bluefin assembly of R/AUV *GI Taylor*

- We collaborated with Bluefin on mechanical design of adaptor ring (see Figure 2)
- Oversaw mechanical design of complete vehicle including instrument placement.
- Oversaw assembly of FAU acoustic modem and modem testing.
- Task 5 will follow Task 1. A limited experiment will be carried out with existing Ocean Explorer AUV during Winter 2002 using an existing AUV team at FAU. A no-cost extension will be requested to complete the work.

- Currently a video system is being designed for the *GI Taylor* AUV to be installed for sea trials at AUTECH. The trials will be carried out in conjunction with a visual survey of the AUTECH region to 1100m depth.

Task 4: A paper entitled “Subsurface Observations of Wind Induced Currents in Littoral Waters” by Chernys and Dhanak, has been submitted to *Journal of Physical Oceanography*. A second paper, entitled “Horizontal and Vertical Distributions of TKE Dissipation Rate in Response to Atmospheric Forcing” is under preparation.

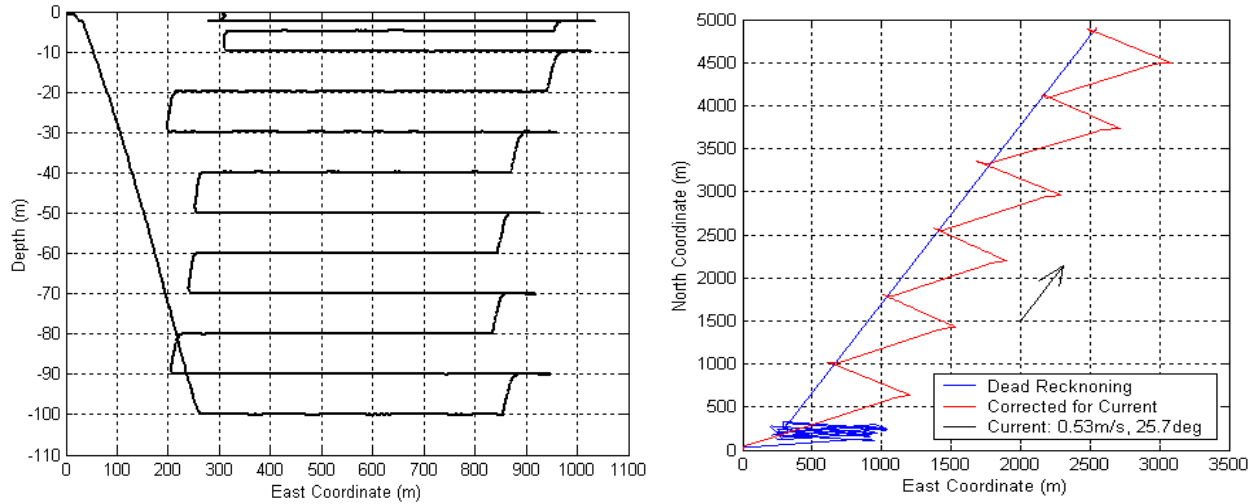
Task 5: In view of the delay in delivery of the vehicle, a few preparatory missions were carried out using the OEX vehicle, which was upgraded in the process so that it now has a new operating system. In particular, two missions were carried out in determining thermocline characteristics in the Florida Current, and a thermocline tracking algorithm has resulted. Details are provided in a MS thesis at FAU, entitled “Thermocline Tracking Using an Upgraded OEX AUV” by M. Clabon. In other work, co-sponsored by FAU, the turbulence package developed in previous work was implemented on a vertically rising profiler. The profiler will complement the AUV surveys in determination of dissipation rate close to the free surface, and add to the microstructure measurement capabilities at FAU. Details of the profiler are given in a MS thesis at FAU, entitled “Design and Testing of an Untethered Vertically Ascending Profiler for Use in Measuring Near-surface Turbulence” by J Bogin.



**Figure 1. (a) The Odyssey III class AUV, the *GI Taylor*, shown with the turbulence package. (b) The back section shown with the adaptor ring on the right for accommodating OEX-based payloads**

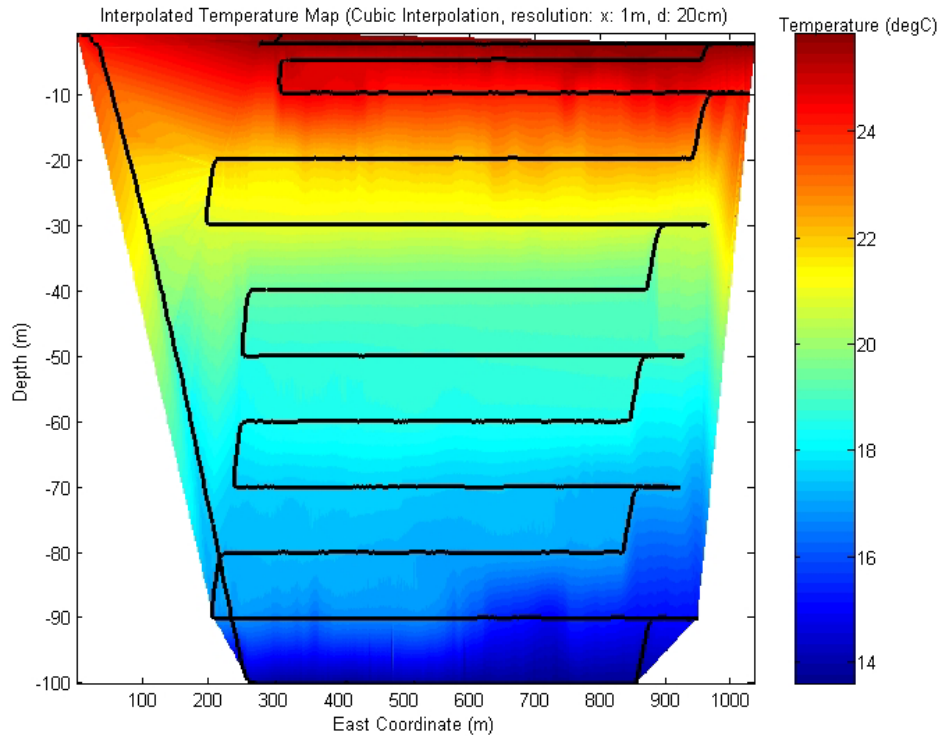
## RESULTS

Detailed results from the missions aimed at identifying thermoclines in the Florida current. Some results from the March 19, 2003 mission are shown below. The AUV went to a depth of 100m and performed a cross-current vertical lawn-mower pattern survey (Figure 2a) in a 0.53 m/s current. The actual planar path is shown in Figure 2b.



**Figure 2. AUV path during mission of March 19, 2003 in the Florida Current.**  
**(a) Side view, (b) Planar View**

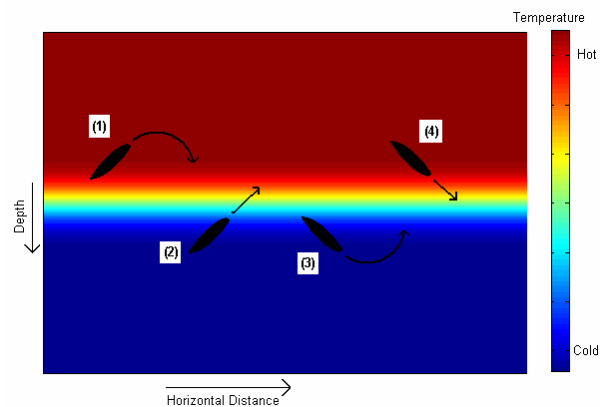
The temperature distribution determined from CTD measurements recorded onboard the AUV is shown in Figure 3. Turbulence data obtained during the survey are being analyzed.



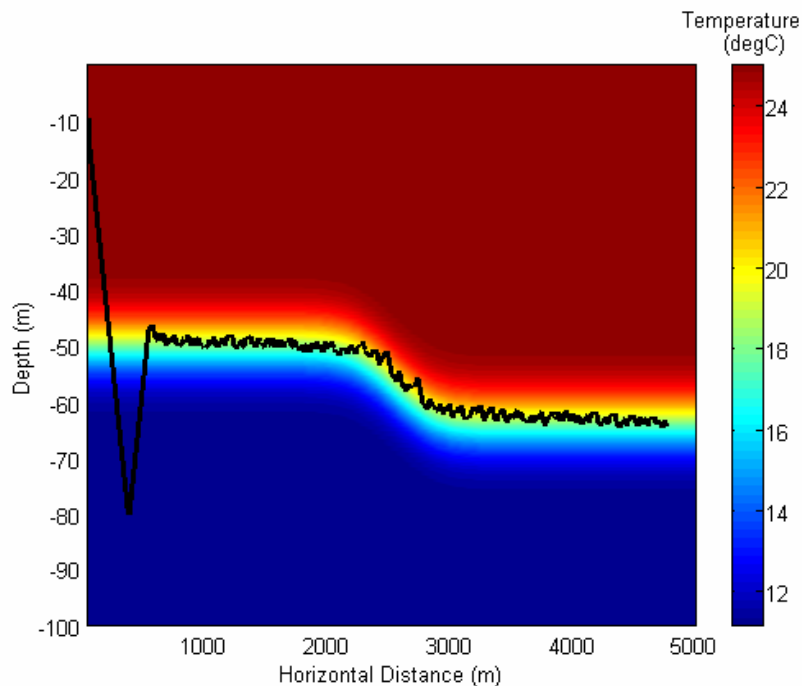
**Figure 3. Temperature distribution in the Florida Current at 26° latitude during March 2003 survey, as determined from the AUV-based measurements.**

A controller algorithm has been designed that takes depth rate and temperature gradient variation as input and provide required stern-plane angle as output in order to maintain position within the

thermocline (Figure 4), using a Fuzzy inference scheme. The simulated result from the algorithm is shown in Figure 5.



**Figure 4. Reflex tracking algorithm concept.**

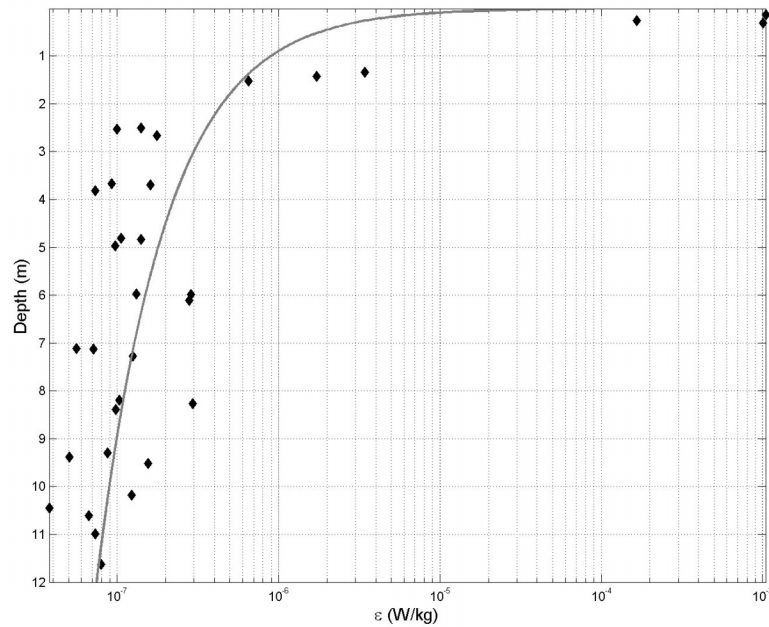


**Figure 5. Simulation of the thermocline tracking algorithm**

A vertical profiler (Figure 6), co-sponsored by FAU, has been developed as an alternate platform for the turbulence package developed for the AUV in previous funding. Initial sample result for the distribution of dissipation rate, off the east coast of Florida, determined using the profiler is shown in Figure 7.



**Figure 6. Vertical Profiler for determining TKE dissipation rate close to the surface.**



**Figure 7. TKE mean dissipation rate during vertical ascent of 14 May 2003 compared with law of the wall prediction for 5 m/s wind speed, as measured at nearby pier.**

## IMPACT/APPLICATIONS

An AUV dedicated for oceanographic measurements will provide quality information about physical subsurface processes, over a range of scales, which underlie synoptic scale observations such as from a satellite or a surface current radar.

## TRANSITIONS

Collaboration with University of Miami, University of Victoria, Canada, and Institute of Ocean Sciences, Canada are continuing. Proposals are being written to NSF, and NOAA for application of the dedicated AUV in longer term oceanographic experiments.

## RELATED PROJECTS

The work is carried out in conjunction with N00014-00-1-0218 and other ONR-322OM/AOSN projects funded at Florida Atlantic University.

## BIBLIOGRAPHY

1. Gregg, M. C. 1987. Structures and fluxes in deep mixed layer. In Dynamics of the Oceanic Surface Mixed Layer, Ed P. Muller, D. Henderson.
2. Mellor, G.L. and T. Yamada. 1982. Development of a turbulence closure model for geophysical fluid problems. Reviews of Geophysics and Space Physics, 20, 851-875.
3. Yu, Y. 1997: Flow and turbulence in a tidal channel, Ph.D. Thesis, University of Victoria, Ca.
4. Gross, T.F. and R.M. Nowell. 1985. Spectral scaling in a tidal layer. J. Physical Oceanography, 15, 496-508.
5. Gross, T.F. and R.M. Nowell. 1983: Mean flow and turbulence scaling in a tidal boundary layer. Continental Shelf Research, 2, 109-126.
6. Jimenez, J. and A. Pinelli. 1998. Turbulence near walls. 13th US National Congress of Applied Mechanics. Gainesville, Florida. June 1998.
7. Osborn, T., D. M. Farmer, S. Vagle, S. A. Thorpe and M. Cure. 1992. Measurement of bubble plumes and turbulence from a submarine. Atmos-Ocean 30, 419-440.
8. Grant W. D. and Madsen, O S. 1986. In Annual Review of Fluid Mechanics. 18. pp 265-305.
9. Gargett, A. E., 1989. Ocean Turbulence. Ann. Rev. Fluid Mech. 21. 419-51.
9. Maxworthy, T. 1997. Convection into domains with open boundaries. Ann. Rev. Fluid Mech. 29, 327-71.
10. Dhanak M. R. and K. Holappa. An Autonomous Ocean Turbulence Measurement Platform. To appear in the special Microstructure Sensors Microstructure Sensors in JOAT (presented at the ONR Workshop at Mt. Hood, Oregon. October, 1996).
11. Dhanak, M. R. and K Holappa., 1998. Turbulence Measurements off the Florida Coast using an AUV. Oceanology '98. Brighton.
12. Fluery, M. and R. G. Lueck. 1994. Direct heat flux estimates using a towed vehicle. J. Physical Oceanography, 24,801-819.
13. Wolk, F., 1997. Near Surface heat flux measurement with a towed vehicle. MS Thesis, University of Victoria, Canada.
14. Donelan M., Shoaling wave experiment - Duck 99, <http://kiowa.rsmas.miami.edu/duck99/>, 1998.
15. Osborn T. R. and Crawford W. R. 1980. In Instruments and methods of air-sea interaction. Ed. L. Hasse, F. Dobson and R. Davis. Plenum Press, NY, pp 369-386.

## PUBLICATIONS

*Subsurface Observations of Wind Induced Currents in Littoral Waters.* M. Chernys and M R Dhanak. 2003. Submitted to *Journal of Physical Oceanography*.

*Horizontal and Vertical Distributions of TKE Dissipation Rate in Response to Atmospheric Forcing.* M Chernys, M. Dhanak, W. Drennan and L. K. Shay. Under preparation.

*Thermocline Tracking Using an Upgraded OEX AUV.* Mathieu Clabon. 2003 MS Thesis, Florida Atlantic University.

*Design and Testing of an Untethered Vertically Ascending Profiler for Use in Measuring Near-surface Turbulence.* Jeffrey Bogin.. 2003 MS Thesis, Florida Atlantic University.

*Oceanic Turbulence Measurements using an AUV Platform,* Manhar Dhanak. Invited Presentation. Ocean Current Turbulence Workshop, Shell Research, Houston, TX, November, 2002

*Oceanic Turbulence Measurements using an AUV Platform,* Manhar Dhanak. Invited Presentation. University of California, Berkeley. February, 2003.

*Oceanography and Turbulence Measurements using AUVs,* M Chernys and M R Dhanak, Poster, Autonomous and Lagrangian Platforms and Sensors Workshop. March 2003, in La Jolla, California.

Oceanographic observations using an AUV platform. M. R. Dhanak. Invited Pres. WHOI. June 2003

Wind-Driven Mass Transport and Eddy Viscosity Distribution in Littoral Waters. M Chernys and M R Dhanak. American Physical Society Meeting. New York November 2003.

*An AUV Survey in the Littoral Zone: Small-scale Subsurface Variability Accompanying Synoptic Observations of Surface Currents.* Manhar R Dhanak, Edgar An, and Ken Holappa. 2001. IEEE Journal of Oceanic Engineering. 26, 752-768.

*Subsurface Structure of an Atmospherically Forced Water Column in Littoral Waters,* M. Chernys, Ph.D. Dissertation, Florida Atlantic University, 2002.

*On the Instability of Cross-Shelf Shear Layer at the Edge of the Florida Current.* M R Dhanak. American Physical Society Meeting. San Diego, CA, November 2001.

*Wind Induced Ocean Currents in Littoral Waters.* M Chernys and M R Dhanak. American Physical Society Meeting. San Diego, CA, November 2001.

*Integrated Observations From Fixed and AUV Platforms in the Littoral Zone at the SFOMC Coastal Ocean Observatory,* M R Dhanak. EOS Transactions Volume 82 No. 47 Abstract OS31D-05. American Geophysical Union Meeting. San Francisco, December 2001.

*Subsurface Observations in a Wind-Driven Flow in Littoral Waters off the East Coast of Florida* M. Chernys and M. Dhanak, EOS Transactions Volume 82 No. 47, Abstract for Poster, American Geophysical Union Fall Meeting, San Francisco, December 2001

*Subsurface Structure of an Atmospherically Forced Water Column in Littoral Waters - AUV-based Survey,* M. Chernys. Invited Lecture, Physical Oceanography Dissertation Symposium I Breckenridge, Colorado, 2002.